FINAL REPORT

DIPA BIOTROP 2018

Development of Ecosystem Health Index in Indonesia

Researchers:

1. **Prof. Dr. Ir. Arief Sabdo Yuwono, MSc**
2. **Prof. Dr. Ir. Yusli Wardiatno, MSc**
3. **Dr. Rahayu Widyastuti, MSc**
4. **Dr. Dewi Wulandari**

MINISTRY OF NATIONAL EDUCATION AND CULTURE
SECRETARIAT GENERAL
SEAMEO SEAMOLEC
SOUTHEAST ASIAN REGIONAL CENTRE FOR TROPICAL BIOLOGY
(SEAMEO BIOTROP)
2018

1. Research Title:	Development of Ecosystem Health Index in Indonesia
2. Research Coordinator	
a. Name:	Prof. Dr. Ir. Arief Sabdo Yuwono, MSc
b. Sex:	Male
c. Occupation:	Professor, Dept. of Civil and Environmental Engineering, Faculty of Agricultural Technology IPB
3. Institution	
a. Name of institution:	Dept. Teknik Sipil dan Lingkungan, IPB
b. Address:	Kampus IPB Darmaga, PO Box 220 Bogor, 16002.
c. Telephone/Fax.:	0251-8627225
d. Email address:	arief.sabdo.yuwono66@gmail.com
4. Research schedule:	9 months
5. Research budget:	

Bogor, 1 December 2018

Endorsed by,	
Deputy Director for Programme	Research Coordinator,
SEAMEO BIOTROP	
Dr. Jesus C. Fernandez	Prof. Dr. Ir. Arief Sabdo Yuwono, MSc
	NIP. 19660321 199003 1 012

Approved by,
Director of SEAMEO BIOTROP

Dr. Ir. Irdika Mansur, M.For.Sc
NIP 19660523 199002 1 001

Table of Content

List of Table

List of Figure

Abstract

Development of ecosystem helath index was based on the fact that up to now there is no single number that represents the quality of the ecosystem in Indonesia that was not consists of merely three parameters, i.e. water, air and land cover, but also should accomodate other components such as biodiversity index IKH), public health (IKM), as well as environmental health (IKL) since all of them are also important indicator for ecosystem health. Therefore, this research aimed to compile and to map health state of aquatic ecosystem, terrestrial ecosystem as well as built ecosystem in Indonesia for the last three years. Besides, the research aim was also to formulate a quantitative approach of ecosystem health assessment that could be a national guideline for environmental management in Indonesia. The last aim of the reseach was to develop a single number representing the ecosystem health by using a quantitative approach, covering aquatic ecosystem, terrestrial ecosystem and built environment. The research is designed to be carried out within three (3) years where the basic data will be extracted from documents of State of the Environmental Report (SoER or SLH) compiled by municipal, provincial and national levels in selected areas during the last three years. The data is also completed by direct field measurements in selected cathment areas in Java Island, covering the health status of aquatic, terrestrial and built environment. Laboratory analysis was conducted in Bogor Agricultural University and in Research Centre for Tropical Biology (SEAMEO BIOTROP), Bogor, Indonesia. The quantitative approach of ecosystem health assessment has been conducted by converting measurement result of six parameters of ecosystem (IPU, IPA, ITH, IKH, IKM and IKL) into an index, i.e. a single number without unit. Each of those parameters was weighed by similar weighing factor, ≅16.7%, so that the total of the weighing factor is 100%. Preliminary result obtained from the first year research campaign indiated that ecosystem health index of the selected areas is in between 62.1-72.3, where score of each municipality is as follows, 62.1 (Sleman Regency), 68.9 (Madiun Regency), 70.3 (Kulonprogo Regency), 72.3 (Malang and Bantul Regencies), whreas for urban areas is 71.6 (Malang Municipality), 75.0 (Yogyakarta Municipality), 75.1 (Bogor Municipality) dan 75.1 (Malang Municipality).

1. Introduction

1.1. Background

a. The assessment of ecosystem health in Indonesia is currently being conducted in different ways among ecologists and environmental scientists. This is closely related to the existing conditions where no single guidance can be used as a national reference which is based on a collective agreement.

b. An alternative assessment of ecosystem health is to use the Environmental Quality Index (IKLH, *Indeks Kualitas Lingkungan Hidup*). This IKLH is adopted from several sources including the Environmental Performance Index (EPI) developed by a study centre at Yale University (http://epi.yale.edu/), the Yale Centre for Environmental Law and Policy along with Columbia University (Centre for International Earth Science Information Network) in collaboration with the World Economic Forum and the Joint Research Centre of the European Commission.

c. Quantitative assessment of the quality of the environment in Indonesia can be based on the existing guidance, i.e. the Ministry of Environment and Forestry report in form of Indonesian Environmental Quality Index (IKLH) published in yearly basis. In this report the quality of the environment is indicated by three (3) criteria, namely air quality, water quality and forest cover.

d. Air quality is expressed in the form of Air Pollution Index (IPU). The air quality parameters included in the calculations are merely two (2), i.e. SO_2 and NO_2, although the national ambient air quality parameters have nine (9) parameters. These two parameters are part of the ambient air quality parameters stipulated in Govermental Regulation (PP, *Peraturan Pemerintah*) No. 41 of 1999 pertaining on Air Pollution Control. In PP 41/1999 air quality parameters include SO_2, CO, NO_2, O_3, Pb, dustfall, TSP (Total Suspended Particulate), $PM_{2.5}$ and PM_{10} (Particulate Matter), and hydrocarbons (HC).

e. Water quality is expressed in a form namely Water Pollution Index (IPA, *Indeks Pencemaran Air*). The water quality parameters calculated in IPA to obtain IKLH cover merely three (3) of 47 parameters, i.e. TSS (total suspended solid), DO (dissolved oxygen), and COD (chemical oxygen demand). As a comparison, the water quality parameters in Governmental Regulation No. 82 of 2001 pertaining on Water Quality Management and Water Pollution Control covers 47 parameters consisting of three (3) physical parameters, 27 inorganic chemical parameters, two (2) microbiological parameters, two (2) radioactivity parameters and 13 organic chemical parameters.

f. Forest cover is expressed as a Forest Cover Index (ITH, *Indeks Tutupan Hutan*) calculated based on the amount of primary forest area (LHP, *Luas Hutan Primer*) and secondary forest area (LHS, *Luas Hutan Sekunder*) defined by the Ministry of Forestry on the total area of the province (LWP). The area of primary forest (LHP) plus secondary forest area (LHS) is equal to the area of forest cover (LTH, *Luas Tutupan Hutan*). Primary forest is forest that has not been subjected to human disturbance or very little disturbance. Secondary forest is forest that grow through natural secondary successions on heavily disturbed forest land such as former mining, livestock, and settled agriculture.

Lack of an Integrated Ecosystem Health Assessment

The absence of an integrated and uniform ecosystem (environment) health assessment system and the importance of immediate research in order to prepare an environmental health index are briefly described in the following points:

- An integrated ecosystem health assessment that covers all types of ecosystems is not currently available. Therefore, research on the preparation of an ecosystem quality assessment system or overall environmental quality needs to be done immediately.
- If this is not promptly done, then the impact of development activities on changes in environmental quality will not proportionally be predicted nationally. In addition, the overall health status of the ecosystem cannot be reported uniformly.
- When this research is conducted, it will produce an index that describes the health of ecosystems (environments) generally applicable in Indonesia covering all types of the existing ecosystems. Ecosystem health status can be calculated and recorded quickly since it is processed with electronic spreadsheets.

1.2. Objectives

The objectives of this research are:

a. Compiling and mapping the health of aquatic ecosystems, terrestrial ecosystems and artificial ecosystems in selected areas of Indonesia.

b. Formulating a quantitative approach to an ecosystem health assessment system that can form the basis for national environmental policy making.

c. Develop a single index that represents the health of an ecosystem that includes aquatic, terrestrial, and artificial ecosystems using a quantitative approach.

1.3. Expected Outputs

The expected outputs after completing this research are:

a. The first output is the compilation of an ecosystem health index that includes aquatic, terrestrial and artificial ecosystems that can be applied in Indonesia.
b. Publication in international scientific journals (once per year).
c. A guidebook and software (electronic spreadsheet) of ecosystem health assessments with quantitative approaches to be sent to ministries related to ecosystem management (Ministry of Environment and Forestry, Ministry of Marine Affairs and Fisheries).
d. An outcome after the index developed is that the authority will have an ecosystem health assessment system by implementing the index nationally and uniformly. In addition, environmental authorities in Indonesia can use this index as the basis for environmental law enforcement policy and environmental protection and management.

2. Benefit and Importance of Research

This research is a type of basic and applied research at the same time, where baseline research includes the formulation of a quantitative approach system in assessing the health of an ecosystem, whereas applied research lies in the implementation part of the ecosystem health index in order to assess environmental conditions. Therefore, the benefits and importance of the results to be gained from the implementation of this research are as follows:

a. Once the ecosystem health index is established, the environmental management authority, the Ministry of Environment and Forestry (KLHK) and the Ministry of Marine Affairs and Fisheries or other authorities will have an integrated quantitative environmental quality assessment system between terrestrial, aquatic, as well as artificial ecosystems.
b. In the process of ecosystem health assessment or environmental quality assessment, the assessor (authority) and the assessed party (district / municipality or other authority) will have the same grip or standard or reference and method in justifying the health of the ecosystem they manage for the same reference .
c. The ecosystem health index to be constructed in this research is a single index that integrates aquatic, terrestrial and artificial ecosystems in an integrated and easy to operate manner because it is built using programmed electronic spreadsheets. With this system, the ecosystem health index will be presented in a straightforward, single-figure, easy-to-understand way.
d. The use of electronic worksheets will be very useful and superior in aspects:
    - The speed of data processing.
    - Accuracy of assessment analysis.
    - Ease of data storage analysis results.
    - Presentation of assessment results.
    - Delivery of assessment results to related parties.

3. Methodology

3.1. Research Components

The components required in the implementation of the research are presented in Table 1. Components consist of research materials, equipment required, both equipment in the form of physical devices and software.

Table 1. Research components

No.	Components	Description
1.	Study Materials	• Journal that has been published related to the condition/ health state of ecosystem in Indonesia. • Regulation on ecosystem management in Indonesia. • National, provincial and district/city environmental status reports (SLHs) for the last 5 years for selected regions. • Ecosystem health data (aquatic, terrestrial and artificial)
2.	Equipment	Data processing software (Excel) and a set of computers.

3.2. Research Roadmap

This study is planned to be conducted within three (3) years. The research roadmap is presented in two forms, namely in **Table 2** and **Figure 1**. Table 3 contains activities undertaken on an annual basis, expected results and expected risks that may occur during the course of the study.

Figure 1 explains the roadmap that this series of research will last for three (3) years and may be continued again in the next two (2) years if the results of this study need to be further explored by the government or required as an important raw material in the preparation of more detailed guidelines. More detailed guidelines could cover the entire ecosystem type and unique ecosystems in Indonesia.

Table 2. Research Roadmaps

Project	Development of Ecosystem Health Index in Indonesia		
Final objectives	An ecosystem health index is established and implemented in Indonesia by 2020		
Year	2018	2019	2020
Activity	• Identification of ecosystem health parameters • Validate the location of terrestrial ecosystems Health • Analysis of terrestrial ecosystems • Preparation of scientific journals	• Validate the location of aquatic ecosystems • Health analysis of aquatic ecosystems • Preparation of scientific journals	• Validation of artificial ecosystem location • Health analysis of aquatic ecosystems • Preparation of scientific journals
Milestones	• The parameters of terrestrial ecosystem health are identified • The index of terrestrial ecosystem index is composed.	• The parameters of aquatic ecosystem health are identified • The index of aquatic ecosystem index is composed	• The parameters of artificial ecosystem health are identified • The index of artificial ecosystem index is composed
Deliverables	• Assessment guidelines for terrestrial ecosystem health • First year publication.	• Assessment guidelines for aquatic ecosystem health • Second year publication	• Assessment guidelines for artificial ecosystem health • Third year publication.
Risk	• Limited data available in relevant institution	• Limited data available in relevant institution	• Limited data available in relevant institution.

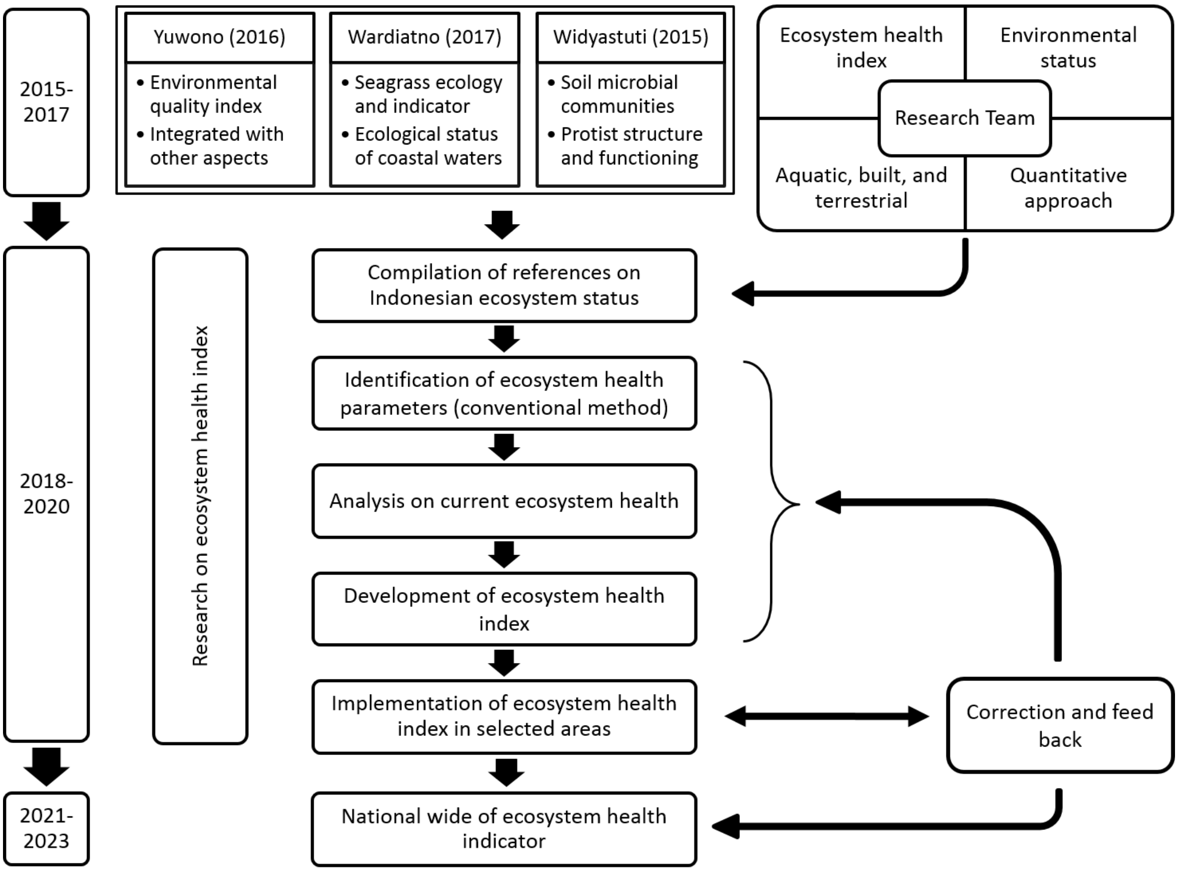

Figure 1. The Indonesian environmental quality index research roadmap

3.3. Preparation Method of Ecosystem Health Index

The study of ecosystem health index (IHE) will be done by following the flow chart presented in Figure 2, while the fish bone diagram is presented in Figure 3. In this diagram, important items of components, methods, instruments and personnel of the research team and their human resources.

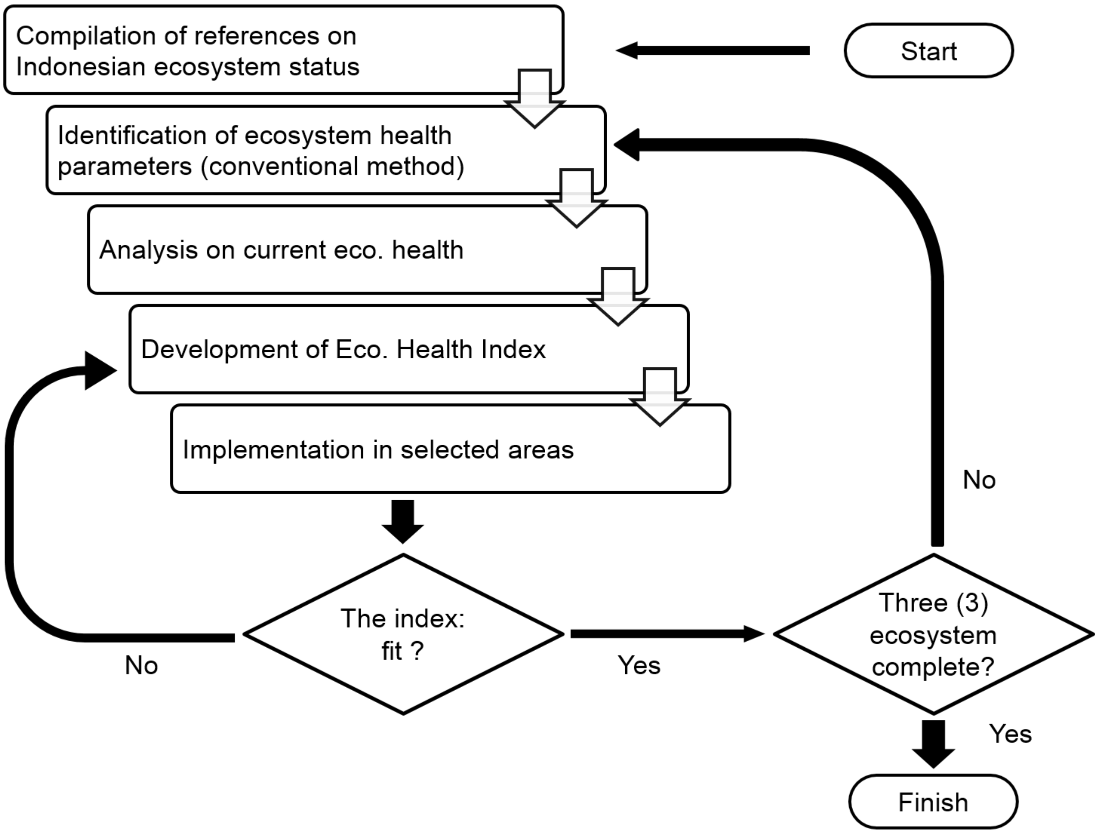

Figure 2. Research flowchart started from compiling status data

Towards the end of the research period, if the ecosystem health index has been formed temporarily, it will be tested to determine whether the index compiled is fit with conditions in Indonesia. If the test results indicate that the index is not suitable, then improvement must be done in the stage of developing index. This stage is done until the complete index (complete) for three (3) types of ecosystem.

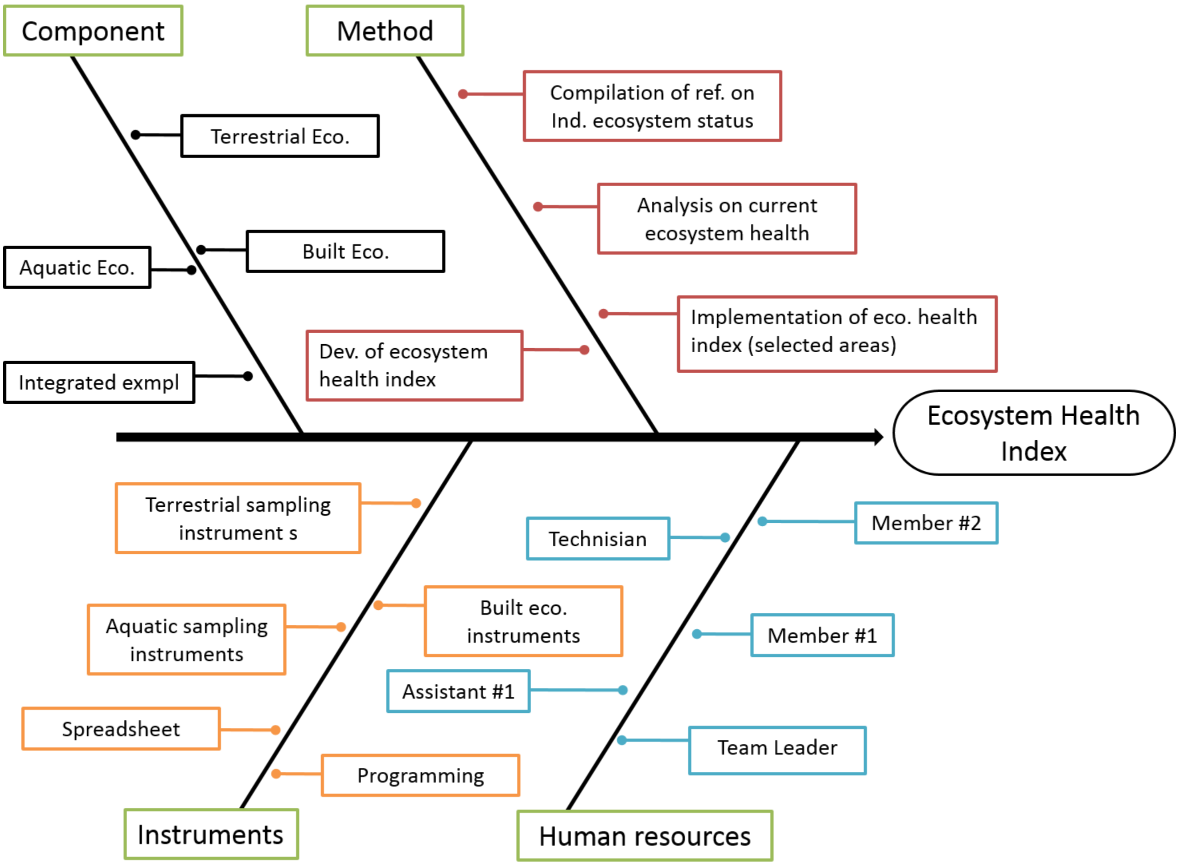

Figure 3. Research activity fish bone diagram

The ecosystem health index will be calculated gradually based on the type of ecosystem (**Figure 4**), which includes:

a. Aquatic Ecosystem Health Index, which consists of ecosystem health indexes for freshwater, marine, sea grass, estuary, and coastal.
b. Terrestrial Ecosystem Health Index which consists of health index for natural forest, savannah, grassland, riparian, and subsurface microbial ecosystem.
c. Built Ecosystem Health Index consisting of urban, rural, crop estate, rice field and plantation forest.

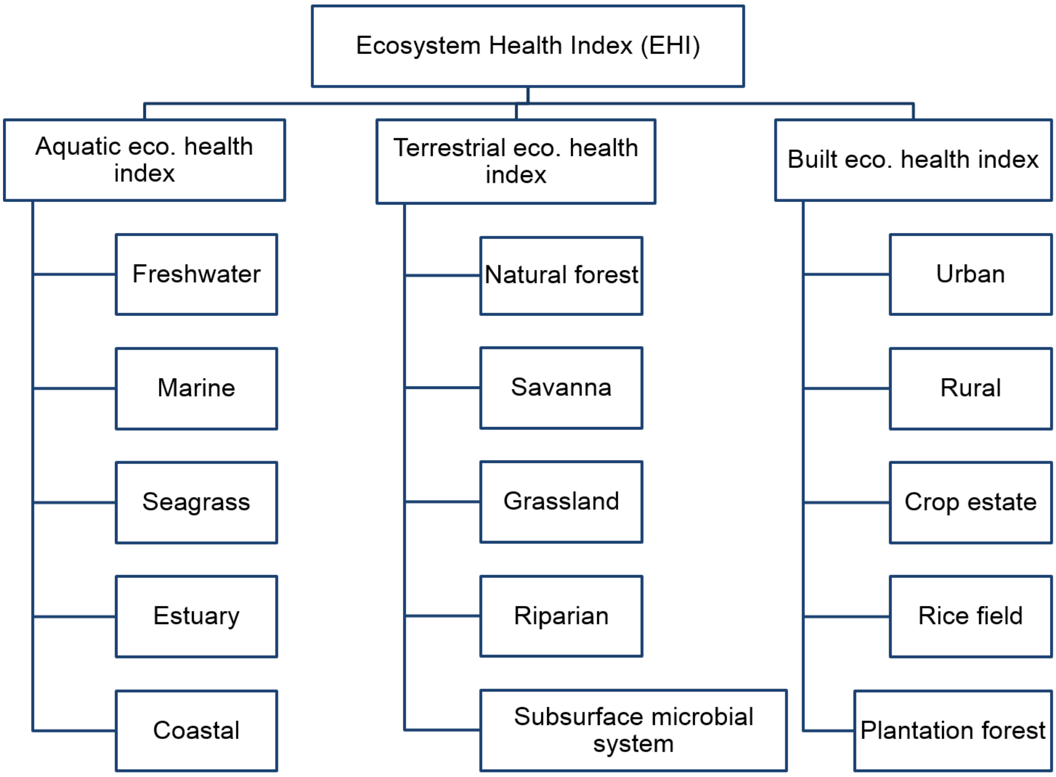

Figure 4. Coverage of ecosystem health index calculations

3.4. Assessment of Built Ecosystem and Terrestrial Ecosystem Health Index

Built ecosystem and terrestrial ecosystem health index can be calculated by using the approach of environmental health index (IKLH). The calculation of environmental health index based on three types of indexes that simply showed at Table 3.

Table 3. Environmental health index components

No	Components of IKLH	Parameters	Quality (%)	Notes
1	Air pollution index (IPU)	• SO_2 • NO_2	30	9 parameters in PP 41/1999
2	Water pollution index (IPA)	• TSS • DO • COD	30	47 parameters of water quality (PP 82/2001)
3	Forest coverage index (ITH)	• Area of primary forest; secondary forest; and forest.	40	Given the biggest quality because it only consist of one parameter (Ref. KLHK)

The equation that used to calculate IPU, IPA, ITH is given below:

IPU NO_2 calculated by using this equation (IKLH 2013):

Air index of IKLH $= 100 - \left[\frac{50}{0,9}\right] \times (EU - 0,1)$

Notes:

IEU : air pollution index model EU (Europe)

If the index of NO_2 and SO_2 parameters have been received, then the air pollution index (IPU) can be calculated as the average score between these two equations:

$$IPU = \frac{IPU\ NO_2 + IPU\ SO_2}{2}$$

Notes:

IPU = air pollution index [-]

IPU NO_2 = air pollution index of NO_2 parameter [-]

IPU SO_2 = air pollution index of SO_2 parameter [-]

IPA or water pollution index can be calculated by using the notation of PI (pollution index) as declined on the second attachment of the Decretal of Environmental and Forestry Minister 115/2003 about The Guidance of determining the water quality status.

Based on that calculation principle, it will be calculated by measuring the concentration of water quality parameters, then comparing with the concentration on standards (L) according to its use as written on Government Law 82/2001 about Water Quality Management and Water Pollution Control. Based on the data that collected and the calculation that measured, the result is the score of pollution index (PI). The equation that will be used is given below:

$$PI_j = \sqrt{\frac{(C_i/L_{ij})_M^2 + (C_i/L_{ij})_R^2}{2}}$$

PI_j = water pollution index (pollution index) for “j”

C_i = concentration of water quality parameter “i”

L_{IJ} = concentration of water quality parameter “i” as written on the standard of water “j”. in this case is the water quality of class II

$(C_i/L_{ij})_M$ = maximum score of (C_i/L_{ij})

$(C_i/L_{ij})_R$ = average score of (C_i/L_{ij})

Forest coverage (TH) is get by calculating the quotient between the total area of primary forest (LHP) and the area of secondary forest (LHS) based on The Decretal of Forestry Minister about the area of the province (LWP) as described below:

$$TH = \frac{LHP + LHS}{LWP}$$

Forest coverage index (ITH) is calculated by using the equation below (IKLH 2014) :

$$ITH = 100 - 84.3 - (TH * 100) * \frac{50}{54.3}$$

Notes:

TH = forest coverage

LHP = the area of primary forest [Ha]

LHS = the area of secondary forest [Ha]

LWP = area of the province [Ha]

ITH = index of forest coverage [-]

84.3 = the area of forest coverage in Papua on 1982 as the ideal reference.

If IPU, IPA, and ITH is done, then IKLH can be done by using an equation which composed by its 3 indexes and followed by the quality of its index that shown below:

$$IKLH = IPU * 30\% + IPA * 30\% + ITH * 40\%$$

IPU, IPA, and ITH is calculated on the province scale to get the IKLH of province. The way to get IKLH on national scale is used the equation that consider the total population of its province. The equation for calculating national IKLH is given below (KLHK 2015):

$$IKLH = \sum_{i=1}^{n} province\ IKLH_i \times \frac{population\ of\ the\ province_i}{national\ population}$$

Notes:

IKLH = national environmental quality index

IKLH province = province environmental quality index

n = the total of provinces.

3.5. The Completion of the Assessment of Health Index

Those assessments are just a little part of the environmental quality indicators because there are some important parameters in the environment that have to be included as the environmental quality indicators, which is biodiversity (flora and fauna), public health, and environment health. Those three parameters and their quantitative measures can be declined as shown below:

- Flora and fauna is declined as biodiversity index (IKH)
- Public health is declined as public health index (IKM)

- Environment health is declined as environmental health index (IKL)

However, the problem to input or not those last three indicators are not stop here, which is need to consider the data availability and its data series in Indonesia. One of the classic and the fundamental problem about data aspect in Indonesia is the availability of the data series.

The score of those three aspects or parameters can be got based on the data of each region in a form of State of the Environment Report (SLH or SoER). Those three indexes can be calculated manually by the supported data that available. Thus, those data series are available in each region or province.

Quantitative assessment of flora and fauna aspect can be declined as biodiversity index such as Simpson Index, Margalef Index or Shannon Index (Canter 1996). As example, biodiversity index by Shannon is given below:

$$H = \sum_{i=1}^{S} (p_i * \ln p_i)$$

Notes :

H = Shannon biodiversity index

P_I = the total individual of species “i”

S = the total species of sample

The correlation of those environmental quality and social welfare can be viewed from the last two aspects that have been mentioned, which is public health and environment health. On BPS catalogue with the title of Public Welfare Indicators on 2015 (BPS 2015) is mentioned that the health indicators are:

- Life expectancy value
- Infant mortality value
- Morbidity value
- Prevalence of infant with malnutrition
- Other indicators that related with the access of health care facilities.

The term of completing the environmental health index here is about public health aspect that consist of morbidity value, mortality value, and life expectancy age (UHH). Morbidity value (prevalence of illness) is the total cases of certain illness around ten thousand population. Mortality value consist of infant mortality, toddler mortality, and maternal mortality. Life expectancy age (UHH) is the age estimation of a person who live in a certain area, it has been calculated usually in each region in Indonesia.

Based on the Decretal of Health Minister 1202/Menkes/SK/VIII/2003 about Indicator of Healthy Indonesia 2010 and the Guidance of Establishing the Indicator of Healthy Province and Healthy Region, indicators of public health consist of mortality indicator, morbidity indicators, and nutritional status indicator. Those indicators are the standard for all of stakeholders to get the similarities of the standard. Environment health aspect consist of followed components:

- Percentage of family that have clean water access
- Percentage of health house
- Percentage of family that have sanitation facilities.

All of those aspects are the important aspects which is fundamental, therefore are important parameters in the assessment of environmental quality. If the assessment environmental quality is not involving these aspects then the emerging value can not indicate a representative character. Abandonment of these aspects will also provide a biased understanding of the real environmental quality.

The involvement of these three aspects (flora and fauna, public health, and environmental health) will bring positive implications of the extension of assessment criteria of environmental quality compared to the last criteria of this assessment. One of the real positive implication and can be immediately seen is the attention of people and stakeholders that all of those aspects also become a measure of environmental quality.

If the value of an aspect is low, then people will try to fix it. And vice versa, if the value which obtained from those aspects is relatively high, then people will strive continuing to maintain or even increasing it.

The fundamental difference between the new version of the Environment Quality Index is in the new version of IKLH and the old version is presented in Figure 5. In the new version, all of the indicators in the old version are retained as important components of the assessment system. Additional components that are also fundamental are Biodiversity Index (IKH), Public Health Index (IKM), and Environmental Health Index (IKL). Each indicator is calculated by using the relevant parameters as presented in **Table 4**.

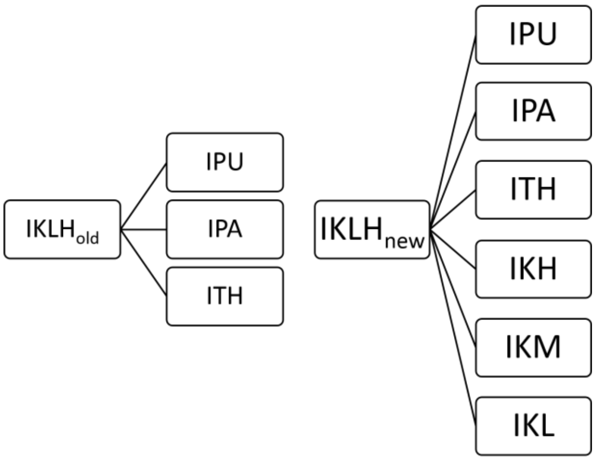

Figure 5. The differences scheme of old version Environmental Quality Index ($IKLH_{old}$) and the new one ($IKLH_{new}$)

Table 4. Additional indicators and measurement parameters of the new index

IKLH	Indicator	Parameters
Old version	IPU (air pollution index)	SO_2 and NO_2
	IPA (water pollution index)	TSS, DO, COD
	ITH (forest coverage index)	LHP, LHS, LKH
New version	IPU, IPA, ITH	[idem]
	IKH (biodiversity index)	Total individuals of one species, total species, total individuals, specific abundance of each species.
	IKM (public health index)	Mortality (infant, toddler, maternal mortality), morbidity, and nutritional status.
	IKL (environmental health index)	Percentage family that have sanitation facility, health house, access to clean water.

Figure 5 shows that the new IKLH includes six indicators which is the three of them are indicators in $IKLH_{lama}$. Thus, it is clear that the new IKLH not only involves three existing indicators, but also consider aspects (indicators) that are much wider than $IKLH_{lama}$.

3.6. Calculation of the Aquatic Ecosystem Health Index

The SingScore biotic index will be used to evaluate and to determine the health level of aquatic ecosystems, especially rivers (Blakely et al., 2014). The index calculation is done by summing the tolerance value of each taxa in each observation station and then dividing it by the number of taxa that exist in that location.

Furthermore, the result will be multiplied by the number 20 so that the SingScore index value can be in the range between 0 and 200. The final value will be classified according to the following classification:

- Bad (SingScore: <80)
- Medium (SingScore: 80-99)
- Good (SingScore: 100 -119), and
- Very good (SingScore:> 120).

In addition, several other indexes will also be calculated to compare, among others, Lincoln Quality Index (LQI), Family Biotic Index (FBI), and Stream Invertebrate Grade Number Average Level 2 (SIGNAL 2).

3.7. Measurement of Soil Health

Structure and function of organisms in the soil can be used as bioindicators to investigate the change of terrestrial ecosystem functions. Soil fauna forms an essential component of terrestrial ecosystems and provide many ecological services, such as litter decomposition and N-mineralization. The change of terrestrial function influenced the soil health. Measurement of population and diversity of soil microbes and fauna can be done to investigate the soil health.

Soil Microbes

Sampling

Soil samples as much as ± one kg were collected from 5 randomized points at the soil depth of 0 – 20 cm. The five soil samples were mixed together to make the composite samples, then it was taken about one kg and put in a plastic bag and labeled. The soil samples were then stored in cool box and transported to the laboratory for further analyzed. Methods and medium that were used to determine soil microbes were presented in Table 5.

Table 5. Methods and medium to determine soil microbes

Microbe Parameter	Methods	Medium
Microbe Total	Plate Counting	Nutrient Agar/Soil Extract Agar
Plate Counting	MPN	Nitrogen-Free B
Phosphate Solubilizing Microbes	Plate Counting	Pikovskaya
Cellulolytic Microbes	Plate Counting	Carboxyl-Methyl/Cellulose (CMC)

Isolation

Plate Counting and Most Probable Number (MPN) methods were conducted using dilution series. Dilution of soil samples was adjusted according the level of soil fertility. The serial dilutions of the soil samples were made from 10 g soil in 90 mL NaCl 0.85% solution and incubated for 2 hours in orbital shaker (10^{-1}) and continued to serial dilution 10^{-5}. For the normal soil, soil samples were diluted up to 10^{-6} and 10^{-7} (total microbes), 10^{-4} and 10^{-5} (for *Azospirillum*), 10^{-3} and 10^{-4} (for Phosphate Solubilizing Microbes and Cellulolytic Microbes).

Soil Fauna

Sampling

Samples were taken in 5 cm soil depth (20 cm x 15 cm) from five randomized points. Undisturbed soil samples were taken using soil corer with 20 cm diameter. Soil samples were then extracted using Berlese Funnel Extractor. The samples were placed in box and were kept during transportation from direct sun.

Extraction

The soil fauna was extracted in Berlese Heat Extractor. A Berlese is a device for collecting and extracting the active stage of small invertebrate animals from soil or litter. The soil sample was put into the box (20 cm x 15 cm) which had a 2.0 mm screen at the bottom holding the soil sample but letting the animals pass through, on top of the box was closed with clothes. About 10 cm above the bucket, a small lamp of 40 watt was placed as a source of heat. The temperature of Berlese was set from 30° C to 50° C gradually for 5 days. The animals within the soil samples were forced to move downward to avoid the heat. They then fell into a box containing alcohol 70% as a preservative. The soil fauna also was stored in vial 50 mL containing alcohol 70% and determined under a stereomicroscope (**Figure 6**).

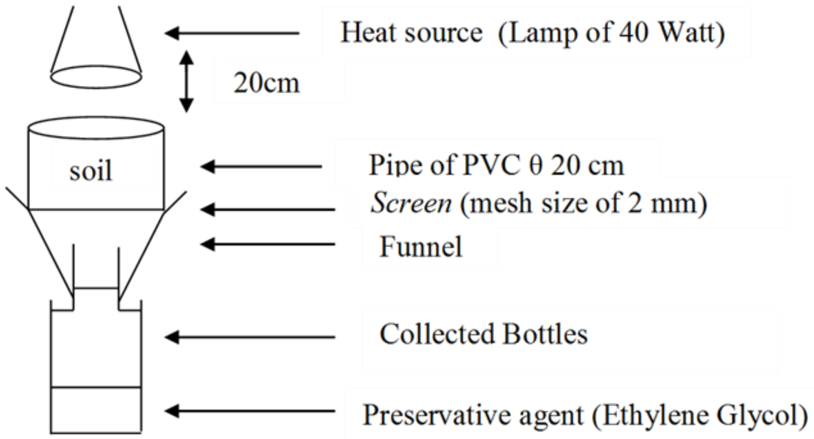

Figure 6. Berlese heat extractor to collect soil fauna

Grouping and Identification

All samples were sorted and counted in the laboratory using a stereomicroscope. All animals were classified into taxonomic orders except for Coleoptera, Hymenoptera, Diplura (were classified into families).

Calculation of Animals Abundance

The number of individuals (abundance or density) of extracted animals was calculated according to Meyer (1996):

$$\mathbf{IS/A = I.cm^{-2}}$$

IS = mean number of individuals per sample

A = surface area of the sampling box (cm^2) was converted into m^2

I = number of individuals

Calculation of Soil Animal Diversity

Diversity indices were calculated according to Shannon's diversity index (Ludwig and Reynold 1988). The equation for Shannon function is:

$$H' = -\sum_{i=1}^{s}\left[\left(\frac{ni}{n}\right)\ln\left(\frac{ni}{n}\right)\right]$$

H' = Shannon's diversity index

ni = number of individuals

n = total number of individuals in the samples

4. Result and Discussion

Application of The Assessment of Ecosystem Health Index

The assessment of the ecosystem health index (EHI) that use the old method introduced since 2009 was a national ecosystem management performance index. This concept was a concept of environmental performance index (EPI) whose criteria include river water quality, air quality, and quality of land cover. EHI from 2009 to 2011 was refined by changing the reference points and calculation methods. A comparison or target for each indicator was a standard or applicable regulation based on the negotiation regulations issued by the government. In 2012 to 2014, EHI was enhanced by methodology development by weighting to produce a dynamic balance between green issues and brown issues. The green issue was all environmental management activities that were sourced from sustainable natural resource management, while the brown issues was an environmental management activity related to the control of pollution and environmental damage.

The refinement of the methodology was again carried out in 2016 to 2017. The calculation of the water quality index used the water quality standard class I according to PP No. 82 of 2001 concerning Management of Water Quality and Control of Water Pollution and the calculation of the land coverage quality index considered aspects of conservation and rehabilitation of changes in land/forest coverage and spatial characteristics of the area (Ministry of Environment and Forestry 2017). The index of the quality of the environment in Indonesia was stated in the regional ecosystem status (RES), then in 2016 changed its name to the ecosystem health index (EHI). There were several differences related to ecosystem health index calculations using the old method and new methods, as used in the calculation of this study. In accordance with the 2015-2019 National Mid Term Development Plan (NMTDP), the policy on ecosystem quality management was directed at increasing EHI which reflects the conditions of water quality, air and land coverage. The difference in the method of calculating the ecosystem health index by using the new methods is illustrated in Table 6.

Variations in the calculation of the index of the health of the ecosystem also various between countries, depending on the concentration of a country on the problems in the country. Malaysia itself applies environmental health assessment with the development and implementation of the national environmental health action plan (NEHAP) which aims to improve the quality of the environment and public health (Ministry of Health, Malaysia 2013). Ecosystem health assessments are also implemented in Thailand, which is on the

2018 World Health Organization page and the Philippines listed on the Department of Health Philippines page in 2018. Different ecosystem health assessments are also applied in China in rural areas (Meng et al. 2018). A comparison of the assessment of the ecosystem health of each country is illustrated in Table 7.

Table 6. The new calculation method of EHI

No.	EHI	Parameters		Weight	Note
1.	The new version	API	SO_2	16.7%	PP No. 41/1999
			NO_2		
			O_3		
			CO		
			TSP		
		WPI	TSS	16.7%	PP No. 82/2001
			DO		
			COD		
		FCI	The area of forest coverage	16.7%	UU No. 41/1999
		BI	Total of flora and fauna species	16.7%	Shannon-Wiener Index
		PHI	Morbidity rate	16.7%	Ecosystem Health Index
			Mortality rate		Infant mortality rate 2012
			Nutrition status		Indonesian Health Profile 2016
			Life expectancy		
		EnHI	Percentage of clean water	16.7%	Ecosystem Health Index
			Percentage of basic sanitation facilities		
			Percentage of healthy houses		Indonesian Health Profile 2016

Source: Yuwono (2012)

Table 7. The calculation metods of EHI in selected countries

Indonesia	Malaysia	Thailand	Filipina	China
Water quality	Water quality	Water and sanitation	Water quality	Rural resources
Air quality	Water, sanitation, and hygiene	Waste management and chemicals and hazardous substances	Solid waste	Rural environment
Land coverage quality	Solid waste and toxic and hazardous materials	Climate change and health impact	Toxic hazardous substances	Rural society
	Toxic chemicals and hazardous substances	Chemical safety and air pollution	Labourer health	Rural economy

Indonesia	Malaysia	Thailand	Filipina	China
	Climate change, ozone depletion, and ecosystem change		Environmental sanitation	
	Sustainable planning, preparation, and response to environmental health emergency			
	Assessment of health impact			

Sources: Ministry of Environment and Forestry (2017); Ministry of Health, Malaysia (2013); WHO (2018); DOH (2018); Meng *et al.* (2018)

The Score of Parameters of Rural Ecosystem Health Index (REHI)

According to Tansley in Gignoux et al. (2011), ecosystems are not objects, but ways to see nature where physical and biological are the main intellectual tools. Rural ecosystems can be defined in two views, the first view defines as natural areas (natural and agricultural land), not including buildings or often called green areas, and the second view defines as non-urban areas or often called rural areas. Therefore, an ecosystem health index (EHI) is needed which can express ecosystem conditions quantitatively. EHI which so far only uses three calculation parameters (air quality, water quality, forest/vegetation coverage) and are not detailed for certain ecosystems. One that can be applied is EHI for rural areas. Based on the data obtained, it is calculated that the new REHI with new parameters that shows the scores listed in Figure 7.

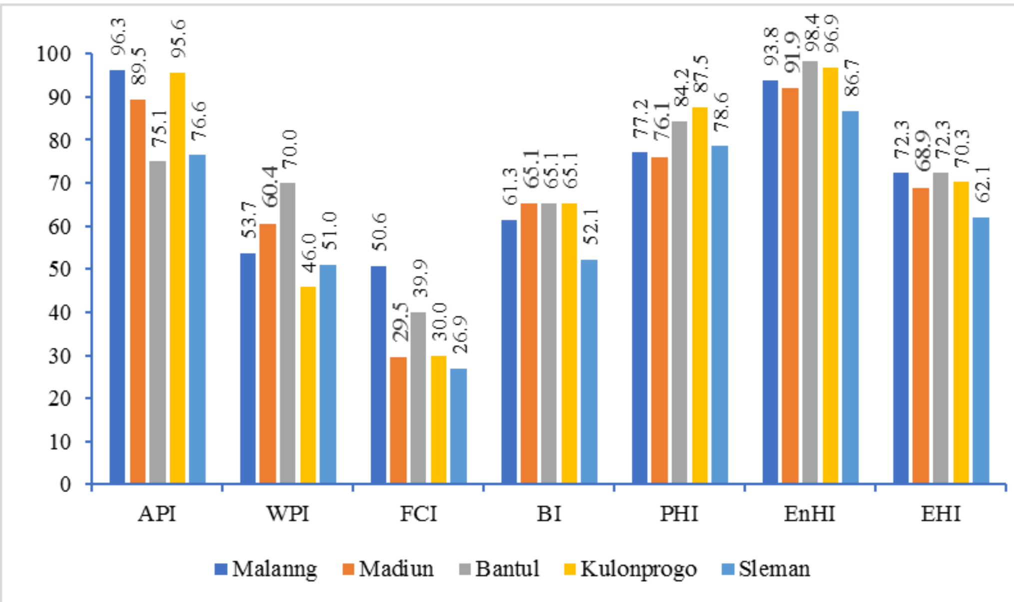

Figure 7. The calculation of REHI

1. Air Pollution Index (API)

Industrial development made air pollution a serious problem and challenge. These problems could be solved by evaluating air quality by surveying several aspects directly, such as temperature, humidity, and others stated in the air pollution index (API). Based on the data that has been processed, the highest air pollution index was in Malang Regency at 96.3 and the lowest in Bantul Regency was 75.1. The cause of the low score could be caused by data that did not found in the new calculation parameters, so that the validity needed to be tested because the calculation of NO_2 and SO_2 in the calculation of API with the old method did not represent air quality in an area. On the one hand, these districts are D and E climates (Schmidt-Fergusson climate category) in Java. Significant changes in score could also be caused by the frequency of monitoring air quality with very different location and time conditions.

2. Water Pollution Index (WPI)

Water pollution index are usually used to assess water quality for different purposes and to communicate that information to others (Sadiq *et al.* 2010). The water pollution index presents one number that explains the overall water quality at a particular location and time based on several water quality parameters (Yogendra and Puttaiah 2008). Water pollution index used in the calculation is the quality of river water because not all regions have water bodies in the form of sea. The calculation in 2016 showed the highest score in Bantul Regency at 70.0 and the lowest in Kulonprogo Regency with a score of 46.0. This could be caused by the limited area of water bodies in Kulonprogo Regency. Kulonprogo Regency has the lowest score because the location of Kulonprogo Regency is in a lower area, so it has entered the river downstream.

3. Forest Coverage Index (FCI)

Forest coverage or vegetation is the appearance of the physical material of the earth's surface. Accurate information is one of the determining factors in improving the performance of ecosystem models, hydrology and atmosphere (Sampurno and Thoriq 2016). This type of cover, changes in what happens, where it occurs, and how much change occurs between certain intervals can be identified and analyzed (Mengistu and Salami 2007, Prayogo 2007, Nugroho and Prayogo 2008, Uzoukwu 2010).

The biggest score of FCI was shown by Malang Regency, amounting to 53.7 with forest coverage area of 1082.3 km^2 to an area of 3534.86 km^2. This differed significantly from other districts which showed that forest coverage was related to the Schmidt-Fergusson climate, where climate area D had greater forest coverage than climate area E. The Schmidt-Fergusson climate classification system used a comparison score (Q) between averages the number of dry months (Md) and the average number of wet months (Mw) in one year (Tjasyono and Bayong 2006). Dry months occur if in one month the amount of rainfall is less than 60 mm, while the wet month occurs if in one month it has more than 100 mm of rainfall. This was because tropical forests cool the climate through evaporative cooling and CO2 absorption (Sanderson et al. 2012).

4. Biodiversity Index (BI)

Biodiversity index were shown by the many types of flora and fauna species from each region. The calculation of BI uses the Shannon-Wiener Index which identified heterogeneities of species. BI in the Shannon-Wiener Index was stated through H' where the higher the H index score, the higher the species diversity, ecosystem productivity, pressure on ecosystems and ecosystem stability (Ismani et al. 2015). In this study, the index calculation in Malang Regency with 54 species showed a greater H' score compared to Sleman Regency, whereas there were 109 species in Sleman Regency, this was due to the numerator score in the Shannon-Wiener index comparison in Malang Regency which tended to be bigger. Scores in the other three districts used an average of national BI because there were no data on biodiversity included.

5. Public Health Index (PHI)

The public health index consists of four parameters, which are morbidity, mortality, life expectancy, and nutritional status. The morbidity rate showed the number of cases that exist and could be handled in the area with data in 2016. Furthermore, the mortality rate was obtained based on the infant mortality rate per 1000 live births in 2012 projected in 2016 from each province where the district was located. Parameters of life expectancy (LE) can be interpreted as the average years of life that will still be lived by someone who has reached age x, in a given year, in the prevailing mortality situation in the community (Central Bureau of Statistics 2018). The last parameter used was the nutritional status of infants aged 0-59 months with the calculation of W/A, H/A, and W/H from each province in 2016. The nutritional status of Bantul, Kulonprogo, and Sleman districts used data from DI Yogyakarta Province, while Malang Regency and Madiun Regency used data from East Java Province. The results of the calculation of the 4 parameters were illustrated in the Table 8.

Table 8. The calculation results of PHI parameters in 2016

Components	**Malang**	**Madiun**	**Bantul**	**Kulonprogo**	**Sleman**
Morbidity	38.9	43.3	18.0	4.7	40.4
Mortality	3.0	3.0	2.5	2.5	2.5
Life expectancy	71	71	75	75	75
Nutritional status (0-59 months)	79.9	79.9	82.6	82.6	82.6

6. Environmental Health Index (EnHI)

Environmental health is an aspect of public health that is related to the way of life, chemicals, and pressures that surround human beings that affect their health and well-being including others around them that play a role in determining environmental quality (Purdon 1971). The environmental health index consists of three parameters, which are the percentage of access to clean water, the percentage of healthy houses, and the percentage of sanitation facilities. All three parameters were compared with the number of heads of households/households from the area used as the object of research.

Access to clean water or quality/decent drinking water is protected drinking water, including tap water (taps), public taps, public hydrants, water terminals, rainwater storage, protected springs, and protected wells. The water does not include bottled water, water from mobile vendors, water sold through tanks, well water, and unprotected springs (Central Bureau of Statistics 2018). A healthy home is a building for shelter and rest and as a means of fostering a family that fosters a healthy life physically, mentally and socially, so that all family members can work productively (Wibisono and Huda 2014). According to the Ministry of Health of The Republic of Indonesia (2012), healthy houses are houses that meet the minimum criteria, which are access to drinking water, access to healthy latrines, floors, ventilation and lighting. Basic sanitation is the sanitation needed to provide a healthy environment that meets health requirements that focus on monitoring various environmental factors that affect the degree of human health (Azwar 1995). Calculation of clean water sanitation based on accumulation of privately owned, shared and public latrines. The results of the calculation of the 3 parameters were illustrated in Table 9.

Table 9. The calculation result of EnHI parametres in 2016

Components	Malang	Madiun	Bantul	Kulonprogo	Sleman
Access to clean water (%)	99.8	94.9	99.3	92.3	62.1
Healthy houses (%)	96.0	96.0	98.4	98.4	98.4
Sanitation facilities (%)	85.6	84.9	97.4	99.9	99.6

Cumulatively, the highest EnHI score was obtained by Bantul Regency and the lowest was in Sleman Regency because in Sleman access to clean water was only obtained for 36,6007 households from 589171 existing households. The other population used access from bottled water or other sources. A condition that was different from other districts.

The Relationship between REHI Score Parameters

The relationship between the parameters of REHI score were illustrated in the graph as a reference between parameters expressed with the score of R^2. The relationship was based on the grouping of green issues and the brown issues. The green issue is that all environmental management activities that are sourced from sustainable management of natural resources and the brown issues is environmental management activities related to the control of pollution and environmental damage (Ministry of Health and Forestry 2017). The first score determined is the relationship between air pollution index and water pollution index as shown in Figure 8.

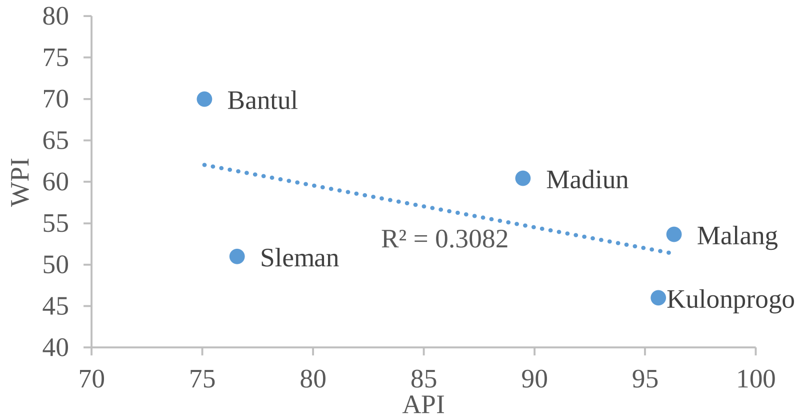

Figure 8. The relationship between API and WPI

The relationship between API and WPI scores in the five sample districts showed a negative correlation, where the higher the API score, the lower the WPI score with R^2 by 0.3082. This score did not show a big number, so it could be seen that the relationship between the two scores was less related to each other. Another relationship is the relationship between API and PHI in the Figure 9.

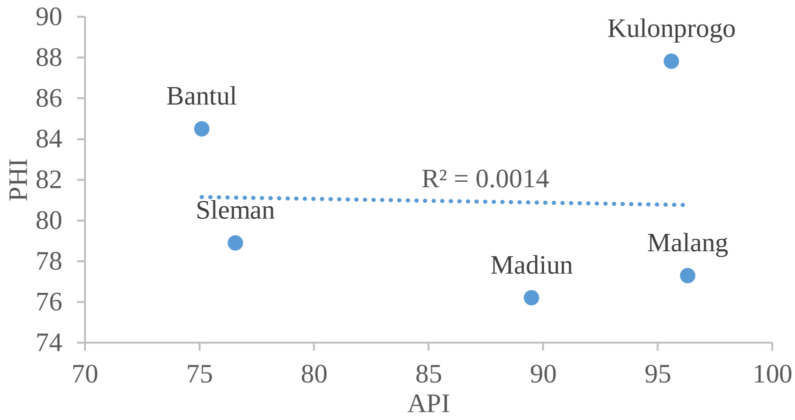

Figure 9. The relationship between API and PHI

Figure 9 shows in the five sample districts it has a negative correlation, where the lower the API score, the higher the PHI score with the very small R^2, which is 0.0007. This score showed that there was no connection between API and rural PHI. Another relationship is the relationship between WPI and PHI as shown in Figure 10.

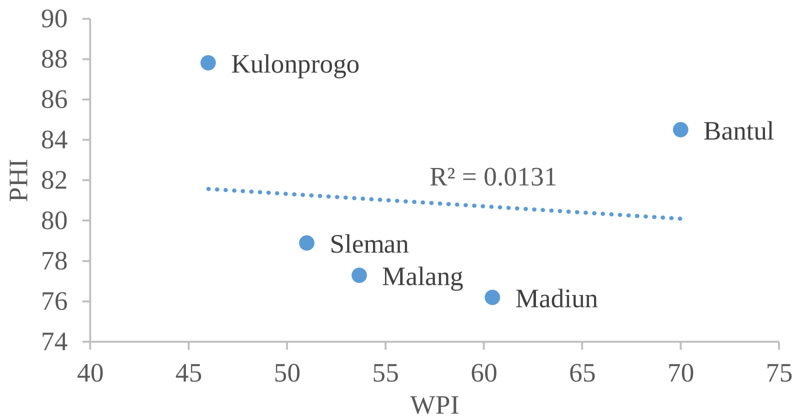

Figure 10. The relationship between WPI and PHI

Figure 10 shows in the five sample districts the negative correlation was found, where the lower the WPI score, the higher PHI score would be, with a very small R^2, which is 0.0131.

This score indicated that there was no connection between the WPI and PHI in rural areas. Another relationship is the relationship between EnHI and PHI in Figure 11.

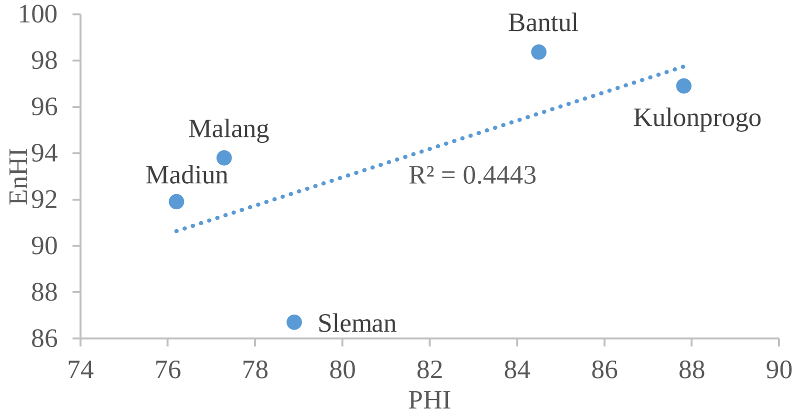

Figure 11. The relationship between EnHI and PHI

Figure 11 shows in the five sample districts it has a positive correlation, where the higher the EnHI score, the higher PHI score with R^2 which is 0.4553. This score indicated the relationship between PHI and EnHI in rural areas was low. The thing that affected the low relationship between parameters in the REHI calculation was the availability of data included in the formulation did not represent real data in the field and differences in the measurement/testing parameters of each area.

5. Conclusions

Based on the purpose of this study, it can be concluded that:

1. The quantitative approach to the rural ecosystem health assessment system was stated in REHI which was calculated with six parameters, i.e. air pollution index (API), water pollution index (WPI), forest coverage index (FCI), biodiversity index (BI), public health index (PHI), and environmental health index (EnHI) and expressed by the equation:

$$REHI = (API + WPI + FCI + BI + PHI + EnHI) / 6$$

2. The results of the analysis of the rural ecosystems health index in Java Island stated that in Madiun Regency and Malang Regency with the D climate the REHI scores were 72.3 and 68.9, in Kulonprogo, Sleman and Bantul Regencies which were the temperate regions of E, the REHI scores were 72.3, 70.3, and 62.1. The average score of rural ecosystem health based on REHI was 69.2 and exceeded the national EHI average in 2016 of 65.73.

6. References

[DOH] *Department of Health, Republic of Philippines*. 2018. *Environmental Health* [Internet]. Manila (PH): *Department of Health*. On: https://www.doh.gov.ph/environmental-health accessed on 6 June 2018 time 16.37 WIB.

[WHO] *World Health Organization*. 2018. *Environmental Health* [Internet]. Nonthaburi (TH): *World Health Organization Country Office for Thailand.* On: www.searo.who.int/thailand/areas/environmentalhealth/en/ accessed on 6 June 2018 time 16.52 WIB.

Azwar A. 1995. *Pengantar Ilmu Kesehatan Lingkungan.* Jakarta (ID): PT. Mutiara Sumber Widya.

Blakely TJ, Hans S. Eikaas, HS, Harding JS. 2014. The Singscore: a macroinvertebrate biotic index for assessing the health of Singapore's streams and canals. *RAFFLES BULLETIN OF ZOOLOGY* 62: 540–548.

Bonato, L., Klarner, B., **Widyastuti, R**., Scheu, S. 2016. The first geophilid centipedes from Malesia: A new genus with two new species from Sumatra (Chilopoda, Geophilidae). Zookeys. 2016 Jul 14; (605):53-71

Borror D.J., C.A. Triplehorn and N.F. Johnson. 2004. An Introduction to The Study of Insects. 7nd Edition. Saunders College Publishing, New York.

Central Bureau of Statistics. 2018. Persentase Rumah Tangga dengan Air Minum Layak [Internet]. Jakarta (ID): Central Bureau of Statistics. On: https://sirusa.bps.go.id/index.php?r=indikator/view&id=478 accessed on 4 June 2018 time 9.24 WIB.

Central Bureau of Statistics. 2018. Umur Harapan Hidup [Internet]. Jakarta (ID): Central Bureau of Statistics. On: https://sirusa.bps.go.id/index.php?r=indikator/view&id=48 accessed on 4 June 2018 time 9.21 WIB.

Ermilov, S.G., Sandmann, D., Klarner, B., **Widyastuti, R**., Scheu, S. 2015. Contributions to the knowledge of oribatid mites of Indonesia. 1. The genus Allogalumna (Galumnidae) with descriptions of two new species (Acari, Oribatida). ZooKeys 529: 71-86 (2015). doi: 10.3897/ zookeys.529.6326.

Gignoux J, Davies ID, Flint SR. 2011. The ecosystem in practice: interest and problems of an old definition for constructing ecological models. *Ecosystems*. 14(1): 1039-1054.

Government of the Republic of Indonesia. 2014. Village. Republic of Indonesia Law Number 6 of 2014. Jakarta (ID): State Secretariat.

Health Department of The Republic of Indonesia. 2012. *Profil Kesehatan Indonesia Tahun 2012*. Jakarta (ID): Health Department of The Republic of Indonesia.

Hefni Effendi, **Yusli Wardiatno**, Mujizat Kawaroe, Mursalin, Dea Fauzia Lestari. 2017. Spatial distribution and ecological risk assessment of heavy metal on surface sediment in west part of Java Sea. IOP Conference Series: Earth and Environmental Science, Vol 54 Tahun 2017.

Ismani L, Lailati M, Rustandi, Sunandar D. 2015. Analisis komposisi dan keanekaragaman tumbuhan di Gunung Dempo, Sumatera Selatan. *Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia.* 1(6): 1397-1402.

Klarner, B., Winkelmann, H., Krashevska, V., **Widyastuti, R**., Scheu, S. 2017. Trophic niches, diversity and community composition of invertebrate top predators (Chilopoda) as affected by conversion of tropical lowland rainforest in Sumatra (Indonesia). PLOS ONE | https://doi.org/10.1371/ journal.pone.0180915 August 1, 2017

Krashevska, V., Klarner, B., **Widyastuti, R**., Maraun, M., Scheu, S. 2016. Changes in Structure and Functioning of Protist (Testate Amoebae) Communities Due to Conversion of Lowland Rainforest into Rubber and Oil Palm Plantations. PLOS ONE | DOI:10.1371/ journal.pone.0160179 July 27, 2016.

Krashevska, V., Klarner, B., **Widyastuti, R**., Maraun, M., Scheu, S. 2015. Impact of tropical lowland rainforest conversion into rubber and oil palm plantations on soil microbial communities. Biology and Fertility of Soils. August 2015, Volume 51, Issue 6, pp 697–705.

Krisanti, M., **Y Wardiatno** and Y M Anzani. 2017. Assessing the ecological status of the Cisadane River's headwaters using benthic macroinvertebrates. IOP Conference Series: Earth and Environmental Science, Vol 54 Tahun 2017.

Kusmana C. 2015. Keanekaragaman hayati (biodiversitas) sebagai elemen kunci ekosistem kota hijau. *Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia*. 1(8): 1747-1755.

Meng L, Huang J, Dong J. 2018. Assessment of rural ecosystem health and type classification in Jiangsu province, China. *Science of the Total Environment*. 625(1): 1218-1228.

Mengistu DA, Salami AT. 2007. Application of remote sensing and GIS inland use/land cover mapping and change detection in a part of South Western Nigeria. *African Journal of Environmental Science and Technology*. 1(5): 99-109.

Ministry of Health and Forestry. 2015. *Indeks Kualitas Lingkungan Hidup Indonesia 2014*. Jakarta (ID): Ministry of Health and Forestry.

Ministry of Health and Forestry. 2017. *Indeks Kualitas Lingkungan Hidup Indonesia 2016*. Jakarta (ID): Ministry of Health and Forestry.

Ministry of Health, Malaysia. 2013. *National Environmental Health Action Plan* (*NEHAP*) *Malaysia.* Selangor (MAL): Ministry of Health Malaysia.

Mitchell B, Setiawan B, Rahmi DH. 2007. *Pengelolaan Sumber Daya dan Lingkungan*. Yogyakarta (ID): Gadjah Mada University Press.

Nugroho SP, Prayogo T. 2008. Penerapan SIG untuk penyusunan dan analisis lahan kritis pada satuan wilayah DAS Agam Kuatan, Provinsi Sumatera Barat. *Jurnal Teknologi Lingkungan*. 9(2): 130-40.

Pramudipta Zahriyani and **Arief Sabdo Yuwono**. 2014. Absorption Capacity of CO_2, NO_2, and Dustfall Emission from Transportation, Industry, and Livestock Sectors in Bogor City by Bogor Botanical Garden. ARPN Journal of Science and Technology. Vol. 4(6): 379-387.

Prayogo T. 2007. Aplikasi SIG untuk memahami fenomena tutupan lahan dengan citra satelit. *Jurnal Teknologi Lingkungan.* 8(2): 37-142.

Purdon W. 1971. *Environmental Health.* New York (US): NY Academic Press.

Sadiq R, Haji SA, Cool GV, Rodriguez MJ. 2010. Using penalty functions to evaluate aggregation models for environmental indices. *Journal of Environmental Management.* 91(3): 706-716.

Sampurno RM, Thoriq A. 2016. Klasifikasi tutupan lahan menggunakan citra Landsat 8 operational land imager (OLI) di Kabupaten Sumedang. *TEKNOTAN*. 10(2): 62-71.

Sanderson M, Santini M, Valentini R, Pope E. 2012. *Relationships between Forests and Weather.* London (UK): Met Office Hadley Centre.

Shannon CE, Wiener W. 1948. *The Mathematical Theory of Communication.* Illinois (US): University of Illinois Press.

Sumpeno W. 2011. *Perencanaan Desa Terpadu*. Banda Aceh (ID) : *Reinforcement Action and Development.*

Tjasyono, Bayong HK. 2006. *Klimatologi.* Bandung (ID): Penerbit ITB.

Uzoukwu CU. 2010. Using GIS to detect changes in land use land cover for electrical transmission line sitting and expansion planning in Winona County. *Papers in Resource Analysis*. 12(1): 11-22.

Wardiatno, Y., Y Qonita, Mursalin, R Zulmi, H Effendi, M Krisanti, A Mashar, S Hariyadi, AA Hakim, A Sahidin, B Widigdo, S Nursiyamah. 2017. Determining Ecological Status of Two Coastal Waters in Western Java using Macrozoobenthic Community: A Comparison between North Part and South Part. IOP Conference Series: Earth and Environmental Science, Vol 54 Tahun 2017.

Wardiatno, Yusli, Puji U. Ardika, Achmad Farajallah, Butet, Nurlisa A, A Mashar, MM Kamal, Eugenius A. Renjaan, Muhammad A. Sarong. 2015. Biodiversity of Indonesian sand crabs (Crustacea, Anomura, Hippidae) and assessment of their phylogenetic relationships. AACL Bioflux 8(2): 224-235, 2015.

Weaver W.R., J.S. Angle J.S. and P.S. Bottomley. 1999. Method of Soil Analysis Part 2. Microbiological and Biochemical Properties. SSSA Book Series 5. Soil Science Society of America, Inc. Madison, Wisconsin, USA.

Wibisono AF, Huda AK. 2014. Upaya peningkatan pengetahuan rumah sehat bagi keluarga. *Jurnal Inovasi dan Kewirausahaan.* 3(1): 17-20.

Yogendra K, Puttaiah ET. 2008. Determination of water quality index and suitability of an urban waterbody in Shimoga Town, Karnataka. Di dalam: Sangupta M, Dalwani R, editor. *Proceedings of Taal 2007: The 12th World Lake Conference*; 2007 Okt 29 – Nov 2; Jaipur, India. New Delhi (IND): Ministry of Environment and Forest. Hal. 342-346.

Yudi Wahyudin, Tridoyo Kusumastanto, Luky Adrianto, **Yusli Wardiatno.** 2016. Jasa Ekosistem Lamun Bagi Kesejahteraan Manusia. Omni-Akuatika 12(3): 29-46, 2016.

Yuwono AS. 2012. Indeks kualitas lingkungan hidup (IKLH) versi baru sebagai dasar implementasi analisis risiko lingkungan. Di dalam: Effendi H, Murtilaksono K, Malahayati S, Rochimawati NR, editor. *Prosiding Seminar Nasional: Mengakrabi Paradigma dan Instrumen Baru Pengelolaan Lingkungan Hidup dalam UU No. 32 Tahun 2009*; 20 Oktober 2011; Bogor (ID): Pusat Penelitian Lingkungan Hidup, Lembaga Penelitian dan Pengabdian Masyarakat, Institut Pertanian Bogor. Hal. 114-122.

Yuwono, A.S. 2011. Indeks Kualitas Lingkungan Hidup (IKLH) Versi Baru sebagai Dasar Implementasi Analisis Risiko Lingkungan. Proceeding Seminar Nasional "Mengakrabi Paradigma dan Instrumen Baru Pengelolaan Lingkungan Hidup dalam UU No.32 Tahun 2009", Bogor, 20 October 2011.

Yuwono, A.S. 2011. The Contribution of Agriculture in A Local Greenhouse Gas Turnover. Proceeding of The 7th Asian Crop Science Association (ACSA) Conference "Improving Food, Energy and Environment with Better Crops", Bogor, 27-30 September 2011.

Yuwono, A.S., Ichwan, N., Saptomo, S.K. 2013. Implementasi Konsep "Zero Waste Production Management" Bidang Pertanian: Pengomposan Jerami Padi Organik dan Pemanfaatannya. Journal Lingkungan Hidup "Bumi Lestari", Vol.13(2): 366-373

Yuwono, A.S., Kurniawan, A., and Fatimah R. 2011. A quantitative approach on the role of urban forest in a local carbon cycle. Proceeding of International Conference of Indonesia Forestry Researchers. Bogor, December 5-7, 2011

Yuwono, Arief Sabdo. 2013. Assessment of Tree Planting Effectiveness to Reduce Greenhouse Gas Emission. Proceeding of The 1st International Conference on Sustainable Agriculture and Environment, Sebelas Maret University (UNS), June 26-29, 2013.

Yuwono, AS., B. Mulyanto, M. Fauzan, F. Mulyani, CR. Munthe. 2016. Generation of Total Suspended Particulate (TSP) in Ambient Air from Four Soil Types in Indonesia. International Journal of Applied Environmental Sciences (IJAES). Vol. 11(4): 995-1006

7. Appendices

Lampiran 1 Data parameter utama IKLH empat kota di Pulau Jawa

Kota	Tahun	Komponen IKLH										
		IPU					IPA			ITH		
		TSP	O3	CO	SO2	NO2	TSS	DO	COD	LHP	LHS	LKH
Jogja	2013	89.03	-	99.23	99.61	95.13	-	1.97	0.88	-	25.16	-
	2014	-	99.80	-	99.94	99.77	-	1.75	5.03	-	25.16	-
	2015	65.80	98.33	98.77	98.05	93.52	6.96	1.85	0.48	-	25.16	-
	2016	66.40	98.81	98.75	99.81	86.57	1.63	1.88	2.25	-	1.48	-
	2017	87.15	98.30	99.03	98.26	97.65	1.05	2.41	1.30	-	1.48	-
Malang	2013	-	98.22	-	98.98	98.32	70.85	97.69	96.78	-	-	1.54
	2014	-	98.13	99.99	99.79	98.30	97.02	96.44	99.03	-	-	-
	2015	99.97	98.50	-	98.30	95.64	98.78	97.33	97.87	-	161.79	-
	2016	99.97	98.50	-	98.30	95.64	91.16	96.14	13.23	-	172.00	-
	2017	99.97	98.50	-	98.30	95.64	97.93	97.23	41.25	-	172.00	-
Bogor	2013	-	-	-	-	-	-	-	-	-	-	-
	2015	75.76	91.88	96.28	98.65	88.28	97.94	98.15	98.64	-	123.72	-
	2016	92.13	77.14	99.42	95.96	90.41	97.74	96.20	97.52	-	45.07	-
DKI Jakarta	2015	43.96	-	94.23	92.01	89.84	93.88	88.11	89.82	-	1101.01	-
	2016	62.43	36.77	99.99	70.06	87.37	92.46	88.03	94.20	-	1101.01	-

* (-) berarti tidak ada data tersedia

Lampiran 2 Data parameter pelengkap IKLH empat kota di Pulau Jawa

Kota	Tahun	Komponen Pelengkap							
		IKH	IKM				IKL		
		Keragaman Hayati	Angka kesakitan	Angka kematian*	Umur harapan hidup*	Status Gizi*	%akses air bersih	%rumah sehat*	%sarana sanitasi dasar
Jogja	2013	61.03	99.14	99.99	74.45	-	99.76	-	99.89
	2014	62.88	57.97	99.99	74.50	-	95.95	-	91.16
	2015	62.88	48.11	99.99	74.68	-	99.74	98.72	99.89
	2016	62.88	73.96	99.99	74.71	87.30	100.00	98.42	100.00
	2017	62.88	81.47	99.99	74.74	83.55	100.00	-	100.00
Malang	2013	71.14	0	99.99	70.34	-	99.92	-	86.58
	2014	52.66	81.71	99.99	70.45	-	100	-	100
	2015	55.26	-	99.99	70.68	-	99.6	95.51	-
	2016	55.39	95.52	99.99	70.74	85.4	100	95.97	100
	2017	55.39	95.52	99.99	70.80	87.5	100	-	84.78
Bogor	2013	-	92.45	99.90	72.09	88.25	-	-	91.44
	2015	62.18	88.27	99.99	72.41	88.25	100	94.75	100
	2016	62.18103138	81.34	99.99	72.44	87.95	100	96.37	100
DKI Jakarta	2015	52.27	94.09	99.85	72.43	81.75	99.97	99.21	89.28
	2016		93.53	100.00	72.49	80.55	100.00	99.51	91.13

*data diambil dari data provinsi
* (-) berarti tidak ada data tersedia

Lampiran 3 Contoh perhitungan indeks kesehatan lingkungan hidup (IKLH) di Kabupaten Sleman pada tahun 2016

1. Indeks pencemaran udara

Lokasi	Parameter					Baku mutu					Indeks					Rata-rata Indeks	Nilai IPU
	SO_2	NO_2	CO	O_3	TSP	SO_2	NO_2	CO	O_3	TSP	SO_2	NO_2	CO	O_3	TSP		
Simpang 4 Condongcatur	19.1	21.6	9280	14.1	222												
Simpang 4 Pasar Godean	22.6	24.4	9280	18.1	215.1												
Simpang 4 Denggung	22.7	25.2	16240	16.9	205												
Depan RSUD Sleman	22.3	19.1	8120	16	155.9												
Depan Kantor Bupati	22.1	37.6	6960	15.9	224.8												
Simpang 3 Pasar Tempel	22.4	36.9	17400	18	377												
Simpang 3 UIN	16.5	24.6	10940	15.2	22.7												
Depan Ambarukmo	14.5	19.2	9280	16.9	94.9												
Simpang 3 Ringroad Maguwoharjo	29.8	25.1	4640	19	671.1												
Simpang 4 Ringroad UPN	16.7	24.1	16420	20.4	248	365	150	10000	235	230	0.1	0.2	1.2	0.1	1.1	0.5	76.6
Simpang 3 Pasar Pakem	17.7	25.5	8120	16.9	298.2												
Simpang 3 Pasar Prambanan	28.1	27.1	5800	21.3	369.1												
Terminal Tlogoputri	14.4	18.1	3480	14.8	167.1												
Depan Kantor Kades Girikerto	15.9	22.6	9280	16.7	199.2												
Simpang 3 Balerante	14.4	25.7	9280	14.5	168.9												
Simpang 4 Demakijo	22.8	21.4	8120	16.8	140.4												
Simpang 4 Jombol	22.1	24.9	24360	15.9	249.5												
Simpang 3 Ngasem	15	19.1	18560	16.1	129.5												
Simpang 3 Pulowatu	14.4	19.4	16240	14.9	472.7												

Lampiran 3 Contoh perhitungan indeks kesehatan lingkungan hidup (IKLH) di Kabupaten Sleman pada tahun 2016 (lanjutan)

Lokasi	Parameter					Baku mutu					Indeks					Rata-rata indeks	IPU
	SO_2	NO_2	CO	O_3	TSP	SO_2	NO_2	CO	O_3	TSP	SO_2	NO_2	CO	O_3	TSP		
Jakal	16.2	18	16920	14.9	223.1												
Simpang 4 Kentungan	18.1	22.2	17120	14.4	229.1												
Simpang 3 Bronggang	17.5	23.5	13920	13.7	311.1												
Depan Kades Umbulharjo	16.3	20.4	6960	14.4	297.1	365	150	10000	235	230	0.1	0.2	1.2	0.1	1.1	0.5	76.6
Simpang 3 Pasar Gamping	22	20.2	18560	16	369.9												
Simpang 4 Barek	22	20.4	18560	16	297												
RSUP Dr. Sardjito	22.6	22.3	9280	18.1	369.9												

2. Indeks pencemaran air

Nama sungai	TSS	DO	COD	TSS	DO	COD	TSS	DO	COD	TSS	DO	COD	(Ci/Lij)R	(Ci/Lij)M	(Ci/Lij)R2	(Ci/Lij)M2	Pij	Status Mutu Air
Opak a	33.00	4.00	11.90	50	4	3	1.52	1.00	0.25	1.90	1.00	-1.99	0.30	1.90	0.09	3.62	1.36	ringan
b		7.90	15.90				1.52	0.51	0.19	1.90	-0.48	-2.62	-0.40	1.90	0.16	3.62	1.37	ringan
c		5.70	12.10				1.52	0.70	0.25	1.90	0.23	-2.03	0.03	1.90	0.00	3.62	1.35	ringan
d		6.30	13.00				1.52	0.63	0.23	1.90	0.01	-2.18	-0.09	1.90	0.01	3.62	1.35	ringan
e		6.30	11.20				1.52	0.63	0.27	1.90	0.01	-1.86	0.02	1.90	0.00	3.62	1.35	ringan
f		6.60	17.10				1.52	0.61	0.18	1.90	-0.09	-2.78	-0.32	1.90	0.10	3.62	1.36	ringan
Tepus a	30.00	5.90	10.00				1.67	0.40	0.30	2.11	-0.99	-1.61	-0.16	2.11	0.03	4.45	1.50	ringan
b		5.80	14.70				1.67	0.69	0.20	2.11	0.19	-2.45	-0.05	2.11	0.00	4.45	1.49	ringan
c		4.40	10.60				1.67	0.91	0.28	2.11	0.79	-1.74	0.39	2.11	0.15	4.45	1.52	ringan
d		3.30	9.10				1.67	1.21	0.33	2.11	1.42	-1.41	0.71	2.11	0.50	4.45	1.57	ringan
e		4.60	17.60				1.67	0.87	0.17	2.11	0.70	-2.84	-0.01	2.11	0.00	4.45	1.49	ringan

Lampiran 3 Contoh perhitungan indeks kesehatan lingkungan hidup (IKLH) di Kabupaten Sleman pada tahun 2016 (lanjutan)

Nama sungai	TSS	DO	COD	TSS	DO	COD	TSS	DO	COD	TSS	DO	COD	(Ci/Lij)R	(Ci/Lij)M	(Ci/Lij)R2	(Ci/Lij)M2	Pij	Status Mutu Air
Kuning a		7.70	12.50				1.72	0.52	0.24	2.18	-0.42	-2.10	-0.11	2.18	0.01	4.76	1.55	ringan
b		7.70	15.40				1.72	0.52	0.19	2.18	-0.42	-2.55	-0.26	2.18	0.07	4.76	1.55	ringan
c	29.00	5.00	11.30				1.72	0.80	0.27	2.18	0.52	-1.88	0.27	2.18	0.07	4.76	1.56	ringan
d		4.80	11.80				1.72	0.83	0.25	2.18	0.60	-1.97	0.27	2.18	0.07	4.76	1.56	ringan
e		4.40	12.10				1.72	0.91	0.25	2.18	0.79	-2.03	0.32	2.18	0.10	4.76	1.56	ringan
Blotan a		7.70	11.40				1.37	0.52	0.26	1.68	-0.42	-1.90	-0.21	1.68	0.05	2.83	1.20	ringan
b		7.50	20.00				1.37	0.53	0.15	1.68	-0.37	-3.12	-0.60	1.68	0.36	2.83	1.26	ringan
c	36.50	5.30	10.60				1.37	0.75	0.28	1.68	0.39	-1.74	0.11	1.68	0.01	2.83	1.19	ringan
d		4.80	21.70				1.37	0.83	0.14	1.68	0.60	-3.30	-0.34	1.68	0.11	2.83	1.21	ringan
e		3.90	13.50				1.37	1.03	0.22	1.68	1.05	-2.27	0.16	1.68	0.02	2.83	1.20	ringan
f		5.10	18.00				1.37	0.78	0.17	1.68	0.47	-2.89	-0.24	1.68	0.06	2.83	1.20	ringan
Progo a		7.60	12.50	50	4	3	1.04	0.53	0.24	1.09	-0.39	-2.10	-0.47	1.09	0.22	1.19	0.84	memenuhi
b	48.00	7.40	11.50				1.04	0.54	0.26	1.09	-0.34	-1.92	-0.39	1.09	0.15	1.19	0.82	memenuhi
c		7.20	10.60				1.04	0.56	0.28	1.09	-0.28	-1.74	-0.31	1.09	0.10	1.19	0.80	memenuhi
Kruwet a		7.00	10.70				1.47	0.57	0.28	1.84	-0.22	-1.76	-0.05	1.84	0.00	3.38	1.30	ringan
b		3.90	13.90				1.47	1.03	0.22	1.84	1.05	-2.33	0.19	1.84	0.04	3.38	1.31	ringan
c	34.00	5.50	16.40				1.47	0.73	0.18	1.84	0.31	-2.69	-0.18	1.84	0.03	3.38	1.31	ringan
d		7.00	12.20				1.47	0.57	0.25	1.84	-0.22	-2.05	-0.14	1.84	0.02	3.38	1.30	ringan
e		5.30	14.00				1.47	0.75	0.21	1.84	0.39	-2.35	-0.04	1.84	0.00	3.38	1.30	ringan
Winongo a		7.00	23.70				1.85	0.57	0.13	2.34	-0.22	-3.49	-0.46	2.34	0.21	5.47	1.68	ringan
b	27.00	4.40	12.40				1.85	0.91	0.24	2.34	0.79	-2.08	0.35	2.34	0.12	5.47	1.67	ringan
c		7.00	19.50				1.85	0.57	0.15	2.34	-0.22	-3.06	-0.31	2.34	0.10	5.47	1.67	ringan
d		6.40	18.00				1.85	0.63	0.17	2.34	-0.02	-2.89	-0.19	2.34	0.04	5.47	1.66	ringan

Lampiran 3 Contoh perhitungan indeks kesehatan lingkungan hidup (IKLH) di Kabupaten Sleman pada tahun 2016 (lanjutan)

Nama sungai	TSS	DO	COD	TSS	DO	COD	TSS	DO	COD	TSS	DO	COD	(Ci/Lij)R	(Ci/Lij)M	(Ci/Lij)R2	(Ci/Lij)M2	Pij	Status Mutu Air
e	27.00	6.80	19.30	50	4	3	1.85	0.59	0.16	2.34	-0.15	-3.04	-0.29	2.34	0.08	5.47	1.67	ringan
f		7.20	17.20				1.85	0.56	0.17	2.34	-0.28	-2.79	-0.24	2.34	0.06	5.47	1.66	ringan
Code a	25.50	7.00	14.00				1.96	0.57	0.21	2.46	-0.22	-2.35	-0.03	2.46	0.00	6.06	1.74	ringan
b		7.40	14.20				1.96	0.54	0.21	2.46	-0.34	-2.38	-0.08	2.46	0.01	6.06	1.74	ringan
c		7.70	15.30				1.96	0.52	0.20	2.46	-0.42	-2.54	-0.17	2.46	0.03	6.06	1.74	ringan
d		7.70	14.70				1.96	0.52	0.20	2.46	-0.42	-2.45	-0.14	2.46	0.02	6.06	1.74	ringan
e		6.40	15.40				1.96	0.63	0.19	2.46	-0.02	-2.55	-0.04	2.46	0.00	6.06	1.74	ringan
f		6.80	17.40				1.96	0.59	0.17	2.46	-0.15	-2.82	-0.17	2.46	0.03	6.06	1.75	ringan
Gadjahwong a	23.00	6.80	13.90				2.17	0.59	0.22	2.69	-0.15	-2.33	0.07	2.69	0.00	7.22	1.90	ringan
b		7.40	11.10				2.17	0.54	0.27	2.69	-0.34	-1.84	0.17	2.69	0.03	7.22	1.90	ringan
c		7.50	14.90				2.17	0.53	0.20	2.69	-0.37	-2.48	-0.05	2.69	0.00	7.22	1.90	ringan
d		5.00	12.50				2.17	0.80	0.24	2.69	0.52	-2.10	0.37	2.69	0.14	7.22	1.92	ringan
e		6.60	14.60				2.17	0.61	0.21	2.69	-0.09	-2.44	0.05	2.69	0.00	7.22	1.90	ringan
f		4.80	11.90				2.17	0.83	0.25	2.69	0.60	-1.99	0.43	2.69	0.19	7.22	1.92	ringan
Konteng a	37.00	4.80	20.40				1.35	0.83	0.15	1.65	0.60	-3.16	-0.30	1.65	0.09	2.74	1.19	ringan
b		6.40	12.10				1.35	0.63	0.25	1.65	-0.02	-2.03	-0.13	1.65	0.02	2.74	1.17	ringan
c		6.80	10.70				1.35	0.59	0.28	1.65	-0.15	-1.76	-0.09	1.65	0.01	2.74	1.17	ringan
d		5.30	21.00				1.35	0.75	0.14	1.65	0.39	-3.23	-0.39	1.65	0.16	2.74	1.20	ringan
e		6.60	19.40				1.35	0.61	0.15	1.65	-0.09	-3.05	-0.50	1.65	0.25	2.74	1.22	ringan
f		6.30	22.30				1.35	0.63	0.13	1.65	0.01	-3.36	-0.56	1.65	0.32	2.74	1.24	ringan
Bedog a	29.00	7.20	15.50				1.72	0.56	0.19	2.18	-0.28	-2.57	-0.22	2.18	0.05	4.76	1.55	ringan
b		7.40	13.20				1.72	0.54	0.23	2.18	-0.34	-2.22	-0.12	2.18	0.02	4.76	1.55	ringan
c		7.70	13.10				1.72	0.52	0.23	2.18	-0.42	-2.20	-0.15	2.18	0.02	4.76	1.55	ringan

Lampiran 3 Contoh perhitungan indeks kesehatan lingkungan hidup (IKLH) di Kabupaten Sleman pada tahun 2016 (lanjutan)

Nama sungai	TSS	DO	COD	TSS	DO	COD	TSS	DO	COD	TSS	DO	COD	(Ci/Lij)R	(Ci/Lij)M	(Ci/Lij)R2	(Ci/Lij)M2	Pij	Status Mutu Air
d	29.00	7.40	12.50	50	4	3	1.72	0.54	0.24	2.18	-0.34	-2.10	-0.08	2.18	0.01	4.76	1.54	ringan
e		6.80	10.10				1.72	0.59	0.30	2.18	-0.15	-1.64	0.13	2.18	0.02	4.76	1.55	ringan
f		6.40	11.20				1.72	0.63	0.27	2.18	-0.02	-1.86	0.10	2.18	0.01	4.76	1.55	ringan

Perhitungan akumulasi indeks pencemaran air (IPA) di Kabupaten Sleman pada tahun 2016

Status	Jumlah	Persen	Koefisien	Nilai
Memenuhi	3	5%	70	3.50
Ringan	57	95%	50	47.50
Sedang	0	0%	30	0.00
Berat	0	0%	10	0.00
Jumlah	60			
IPA				**51.00**

3. Indeks tutupan hutan

Wilayah	Luas Wilayah (km^2)	Luas Tutupan Hutan (km^2)	Hutan/Luas Wilayah	Indeks Tutupan Hutan
Kab. Sleman	574.82	28.0415	0.048783097	**26.87**

4. Indeks keanekaragaman hayati

Golongan	Jenis Spesies	Jumlah Spesies (asumsi 1)	Pi	Indeks Shannon
Hewan menyusui	11	11	0.100917	-0.23145
Burung	93	93	0.853211	-0.13545
Reptil	1	1	0.009174	-0.04304
Ikan	3	3	0.027523	-0.09888

Lampiran 3 Contoh perhitungan indeks kesehatan lingkungan hidup (IKLH) di Kabupaten Sleman pada tahun 2016 (lanjutan)

Golongan	Jenis Spesies	Jumlah Spesies (asumsi 1)	Pi	Indeks Shannon
Keong	0	0	0	0
Serangga	0	0	0	0
Tumbuh-tumbuhan	1	1	0.009174	-0.04304
Jumlah	109	109	1	0.551858
IKH				52.10913

5. Indeks kesehatan masyarakat

Nama penyakit	Jumlah	Jumlah Penduduk	Perbandingan angka kesakitan	Angka kematian	Umur harapan hidup	Status gizi
Nasofaringitis akut	86350.0	1079210.0	0.4	25.0	74.7	82.6
Hipertensi primer	83412.0					
Penyakit pulpa	58504.0					
Gangguan lain pada jaringan otot	35905.0					
Dispepsia	35622.0					
Diabetes mellitus	33987.0					
Infeksi akut lain pd pernafasan atas	24880.0					
Nyeri kepala	23498.0					
Demam tidak diketahui sebabnya	33192.0					
Faringitis akut	20620.0					
		59.6		97.5	74.7	82.6
IKM			78.6			

Lampiran 3 Contoh perhitungan indeks kesehatan lingkungan hidup (IKLH) di Kabupaten Sleman pada tahun 2016 (lanjutan)

6. Indeks kesehatan lingkungan

Persentase air bersih		**Persentase sarana sanitasi dasar**		**Persentase rumah sehat**
Sumur	343734	Bersama	17143	
Ledeng	20969	Sendiri	300978	98.4
Sungai	0	Umum	0	
Hujan	1304	Tidak ada	1309	
Lainnya	223164			
Total	589171	Total	319430	
	62.12		99.59	98.42
IKL		**86.71**		

Lampiran 4 Dokumentasi penelitian

Visit to Batu Municipality

Malang Regency

Malang Regency: example view

Visit to TPA Talangagung, Malang

Water sample collection

Transfer station in Malang Regency

Lampiran 5 Foto-foto organisme makroinvertebrata benthik


Tetragnatha sp.


Larva *Copelatus* sp.


Stenelmis sp.


Larva *Stenelmis* sp.


Larva *Dineutus* sp.


Scirtes sp.


Bibiocephala sp.


Bezzia sp.


Simulium sp.


Gerris sp.


Elophila sp.


Climacia sp.

Lampiran 5 Foto-foto organisme makroinvertebrata benthik (lanjutan)

Nemoura sp.

Agapetus sp.

Hydropsyche sp.

Ochrotrichia sp.

Oecetis sp.

Phryganea sp.

Pupa *Hydropsychidae*